Paper ID: 72328
student

IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM (A1)
Medical Care for Humans in Space (3)

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EXTRATERRESTRIAL SILICATES ARE HEMOSTATIC AND MANAGE BLEEDING IN A SWINE MODEL OF LIVER LACERATION: HEMORRHAGE CONTROL MATERIALS FOR LONG-TERM SPACE MISSIONS

Abstract

Background: Hemorrhage due to trauma is a potential cause of death for astronauts in future long-term space missions. Our blood has evolved to react to silicates on earth to help stop bleeds. Coagulation factor XII (FXII) is activated by silicates in soil to clot blood in wounds. Silicates are also incorporated in some hemostatic materials, such as gauze used for hemorrhage control during trauma. Soils with a high silicon content, accelerate clotting in a FXII-dependent manner. Extraterrestrial soil simulants (ETSS) and meteorite samples have high silicon concentrations like terrestrial soils and may translate to effective in situ hemostatic agents for long-term space missions.

Methods: Several ETSS, including Lunar Highlands and Mare Simulants (LHS-1 and LMS-1, respectively), Mars Global Simulant (MGS-1), and crushed Northwest Africa 869 chondrite (NWA-869) meteorite, were assessed for hemostatic potential. A blood plasma turbidity-based clotting assay was used to compare blood clotting times of normal control plasma and FXII deficient plasma when ETSS were added. In another blood clotting assay, thrombin generation was measured by a fluorogenic assay to assess the hemostatic potential in vitro. FXIIa activity was determined with a chromogenic FXIIa substrate assay in normal control plasma with or without an inhibitor of FXIIa after ETSS treatment. To assess the clotting potential of ETSS in vivo, MGS-1, LHS-1 and NWA-869 were applied in a swine model of liver bleeding. Soils were loosely placed on gauze and administered to a 2 cm long by 1 cm deep incision, and the clotting times and blood loss were compared to plain gauze.

Results: LHS-1, LMS-1, MGS-1 and NWA-869 all significantly accelerated in vitro clot formation ($p<0.01$) compared to no treatment. LHS-1, LMS-1 and MGS-1 also induced more thrombin generation ($p<0.01$) and collectively induced more FXIIa activity ($p<0.05$) in normal plasma compared to no treatment, but not in FXII inhibited plasma. In vivo, LHS-1 and MGS-1 tended towards faster clotting times ($p=0.25$ and $p=0.29$, respectively) compared to plain gauze alone, with NWA-869 meteorite significantly reducing clotting times ($p<0.01$). Collectively, ETSS and NWA-869 reduced blood loss in pigs following administration to deep liver lacerations: 25.52 mL +/- 5.34 mL (mean +/- SEM, n=18) compared to 69.47 mL +/- 25.45 mL (n=7) in normal gauze ($p=0.02$).

Conclusions: In future long-term space missions on the Moon and Mars, extraterrestrial soils may be useful to produce products for hemorrhage control in situ to lessen the burden on payload constraints.